APPENDIX C
STREAM TEMPERATURE, SHADE AND RIPARIAN VEGETATION ASSESSMENT FOR BIG CREEK AND TWELVEMILE CREEK

St. Regis TMDL Planning Area

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March 2007

Project No. B15532.02

INTRODUCTION

Temperature impairments were assessed within Big Creek, Twelvemile Creek, and the St. Regis River using a combination of in-stream temperature measurements, riparian canopy density and shading assessments, mid-summer streamflow measurements, and modeling. This assessment was conducted to aid in the development of Total Maximum Daily Loads (TMDLs) in the St. Regis TMDL Planning Area (TPA). Data collected during this assessment was used in the QUAL2K model to assess the influence of shading on stream temperatures based on existing riparian shading conditions and potential riparian shading conditions along Big Creek and Twelvemile Creek. Along the St. Regis River, riparian canopy density data was collected to "ground-truth" the canopy density assessment performed in 2003. Methods employed in this assessment are described in *Field Monitoring and Temperature Modeling Sampling and Analysis Plan for the 2006 Field Season* (MDEQ 2006a). As outlined in the Sampling and Analysis Plan for this project, the objectives of this assessment are to:

- Evaluate stream water temperatures and riparian shading along Big Creek and Twelvemile Creek
- Evaluate canopy density along the St. Regis River

Additional information relevant to the riparian condition in the St. Regis TMDL Planning Area can be found in **Appendix B** (Item 11: Stream Channelization and Encroachment), **Appendix J** (Stream Temperature Data 2001-2003), and **Appendix K** (Canopy Density Assessment for the St. Regis River TMDL) in the *Draft St. Regis Watershed Water Quality Restoration Plan: Sediment and Temperature TMDLs* completed in June of 2006 (MDEQ 2006b).

Temperature Impairments

Water bodies in the St. Regis TPA listed as impaired due temperature on the 2004 303(d) List include the St. Regis River, Big Creek, and Twelvemile Creek. On the 1996 303(d) List, Big Creek, Deer Creek, Silver Creek, and Ward Creek were listed as impaired due to temperature. No additional assessments were performed on Deer Creek and Ward Creek, since temperature data collected in 2001 indicated the temperature never exceeded 59°F (12°C) (MDEQ 2006b), which is considered the upper limit for bull trout rearing (USFWS 1998). No additional assessments were performed on Silver Creek, since temperature data from 2001 suggested elevated stream temperatures were the result of natural conditions (MDEQ 2006b).

Montana Water Quality Standards

Montana's water quality standards for temperature were originally developed to address situations associated with point source discharges, making them somewhat awkward to apply when dealing with primarily nonpoint source issues. In practical terms, the temperature standards address a maximum allowable increase above "naturally occurring" temperatures to protect the existing temperature regime for fish and aquatic life. Additionally, Montana's temperature standards address the maximum allowable rate at which temperature changes (i.e., above or below naturally occurring) can occur to avoid fish and aquatic life temperature shock. The State of Montana considers the St. Regis River, Big Creek, and Twelvemile Creek B-1 waters. For waters classified B-1, the maximum allowable increase over naturally occurring temperature (if

the naturally occurring temperature is less than 66º Fahrenheit) is 1°F and the rate of change cannot exceed 2°F per hour. If the naturally occurring temperature is greater than 67º F, the maximum allowable increase is 0.5º F [ARM 17.30.623(e)].

BIG CREEK AND TWELVEMILE CREEK TEMPERATURE ASSESSMENT

Temperature assessments along Big Creek and Twelvemile Creek were conducted to identify existing conditions and determine if anthropogenic disturbances have led to increased stream temperatures. This assessment utilized field data collection and computer modeling to assess stream temperatures relative to Montana's water quality standards.

Field Data Collection

Data collection on Big Creek and Twelvemile Creek in the 2006 field season included temperature measurements, streamflow measurements, and an assessment of riparian shading. Methods employed in this assessment are outlined in *Field Monitoring and Temperature Modeling Sampling and Analysis Plan for the 2006 Field Season* (MDEQ 2006a).

Temperature Measurements

Temperature monitoring occurred on Big Creek and Twelvemile Creek over a two-month timeframe in the summer of 2006. The study timeframe examines stream temperatures during the period when streamflow is lowest, temperatures are warmest, and negative affects to the cold water fishery and aquatic life beneficial uses are likely most pronounced. Temperature monitoring consisted of placing temperature data logging devices at 19 sites, with 10 sites in the Big Creek watershed and 9 sites in the Twelvemile Creek watershed. Temperature data logging devices were deployed on July 10th and 11th and retrieved on September 11th through 14th. Temperature monitoring sites were selected to bracket stream reaches with similar hydraulics, riparian vegetation type, valley type, stream aspect, and channel width, so that the temperature data collected during this assessment could be utilized in the QUAL2K model. A summary of temperature data is presented in **Attachment A**.

Streamflow Measurements

Streamflow was measured at the 19 sites where temperature data logging devices were placed on Big Creek and Twelvemile Creek. Streamflow was measured during mid-summer base flow conditions, with measurements performed on August 14th on Big Creek and August 17th on Twelvemile Creek. Streamflow data collected during this assessment was used in the QUAL2K model to help determine if in-stream temperatures exceed Montana standards. Streamflow data is presented in **Attachment B**.

Riparian Shading

Along Big Creek and Twelvemile Creek, riparian shading was assessed using a Solar Pathfinder, which measures the amount of shade at a site in 1-hour intervals. The Solar Pathfinder was used to assess riparian shading along 14 reaches, with 8 reaches in the Big Creek watershed and 6 reaches along Twelvemile Creek using the August template for the path of the sun. Reaches extended from one temperature monitoring site to the next site downstream, with an additional reach from the headwaters to the uppermost temperature monitoring site. Each reach was

considered equivalent to a segment in the QUAL2K model and covered a segment of stream with a consistent riparian vegetation type, valley type, stream aspect, and channel width. In the QUAL2K model, additional reach breaks were placed where the existing riparian vegetation differed from the potential riparian vegetation condition due to anthropogenic disturbances. Within each reach, shade was measured at three sites distributed evenly along the reach. In addition to the Solar Pathfinder measurements, the following measurements were performed at each site in which riparian shading was assessed:

- Stream azimuth
- Stream aspect (0, 45, 90, -45)
- Bankfull width
- Wetted width
- Dominant tree species
- Dominant tree height
- Tree-to-channel distance at bankfull
- Percent overhang
- Shade controlling factor (topography, conifer, willow)
- Potential community type

Field notes were also recorded at each Solar Pathfinder measurement site, with discussions regarding the following categories:

- Description of human impacts and their severity
- Description of existing riparian vegetation and shading conditions
- Description of potential riparian vegetation and shading conditions
- Description of natural and anthropogenic factors affecting shading

This data was used to assess existing and potential riparian shading conditions relative to the level of anthropogenic disturbance at a site. Measurements obtained with the Solar Pathfinder were utilized in the QUAL2K model to help determine if in-stream temperatures exceed Montana standards. Solar Pathfinder data is presented in **Attachment C** and field notes collected at each Solar Pathfinder site are presented in **Attachment D**.

QUAL2K Model

The QUAL2K model was used to assess temperature impairments in Big Creek and Twelvemile Creek relative to Montana's temperature standards for B-1 waterbodies. The purpose of modeling stream temperature with QUAL2K is to help determine if anthropogenic disturbances in the watershed have lead to an increase in stream temperatures. The riparian shade and mid-summer streamflow data collected in 2006 were used directly in QUAL2K to simulate expected stream temperatures, while actual stream temperature data collected in 2006 were used to calibrate the model. The potential riparian shade condition was then used to model stream temperatures in the absence of anthropogenic disturbance. Potential riparian shading was determined based on reference reaches identified during field data collection and aerial imagery review. The relationship between anthropogenic disturbance and water quality impairments as described in ARM 17.30.623(e) was evaluated with the following definitions since almost all

water temperature measurements were below 66°F and temperatures found above 66°F are not likely naturally occurring:

- If simulated stream temperatures derived from the model using the existing riparian shade data deviate by less than 1ºF from stream temperatures derived using the potential riparian shade, then anthropogenic sources are assumed to not be causing or contributing to violations of the relevant B-1 water temperature standards and the stream is not considered impaired due to anthropogenic (or anthropogenically induced) thermal modifications.
- If simulated stream temperatures derived from the model using the existing riparian shade data deviate by greater than 1ºF from stream temperatures derived using the potential riparian shade, then anthropogenic sources are assumed to be causing or contributing to violations of the relevant B-1 water temperature standards and the stream is considered impaired due to anthropogenic thermal modifications.

The QUAL2K model computes the amount of solar radiation entering the water at a particular latitude and longitude. The QUAL2K model tracks a column of water as it travels between two points which are defined by the user. In the QUAL2K model, "effective shade" was defined as the fraction of solar radiation blocked by vegetation and topography. Effective shade data collected in each reach using the Solar Pathfinder was used directly as the input variable in the "Shade" worksheet of the model, where effective shade is entered for the reach in one-hour intervals. Integrated hourly effective shade for each reach was entered as a percent for each hour (e.g. the value at 12:00 AM is applied from 12:00 to 1:00 AM). The QUAL2K model is available at http://www.epa.gov/ATHENS/wwqtsc/html/qual2k.html.

Data Sources and Model Assumptions

Data sources and model assumptions made during this assessment included:

- Shade values extrapolated from the individual Solar Pathfinder measurement sites to the reach scale were assumed to accurately reflect the overall reach condition. In instances where this did not appear to be the case, specific Solar Pathfinder measurement site data was used to represent localized conditions. This situation occurred in lower Twelvemile Creek where conditions varied based on the level of anthropogenic disturbance. In the Big Creek watershed, solar pathfinder measurements from reference sites in the upper portions of Middle Fork Big Creek and East Fork Big Creek were used to estimate potential riparian shading conditions in impacted reaches of the West Fork Big Creek.
- At the headwaters, the water temperature was assumed to be the same temperature as the groundwater, which was estimated to be 10.2ºF based on well data in the St. Regis area obtained from the Ground-Water Information Center (GWIC) database (http://mbmggwic.mtech.edu/).
- The Remote Automated Weather Station at Pardee (http://www.wrcc.dri.edu/), which is east of the St. Regis watershed at an elevation of 4,640 feet, was selected as the most representative site with data for air temperature, dew point, and wind speed.
- The U.S. Geological Survey's National Hydrography Dataset (NHD) stream layer was used to measure distance (http://nhd.usgs.gov). This layer is likely shorter than the actual stream distance resulting in less "residence" time for an individual water molecule in the QUAL2K model.

- Tributary streams were treated as discrete point-source inputs in the QUAL2K model for streamflow and temperature. Tributaries streamflows used in the model were based on field measurements, field estimates, and comparative watershed size.
- The QUAL2K model provides results in degree Celsius, while Montana's water quality standards are presented in degrees Fahrenheit. Conversions are provided in **Table C-1**.

Table C-1. Degrees Celsius Converted to Degrees Fahrenheit

Degrees C	Degrees F	Degrees C	Degrees F	Degrees C	Degrees F
0	32.0	**8**	46.4	**16**	60.8
1	33.8	**9**	48.2	**17**	62.6
2	35.6	**10**	50.0	**18**	64.4
3	37.4	**11**	51.8	**19**	66.2
4	39.2	**12**	53.6	**20**	68.0
5	41.0	**13**	55.4	**21**	69.8
6	42.8	**14**	57.2	**22**	71.6
7	44.6	**15**	59.0	**23**	73.4

Twelvemile Creek Modeled Temperatures

The following steps were taken to calibrate and run the various shading scenarios in the QUAL2K model for Twelvemile Creek:

1. Solar Pathfinder data was collected along six reaches in the field between each of the temperature data logger sites with one reach upstream of the uppermost data logger site. In the field, reaches were labeled TM01 through TM06 progressing in the downstream direction. Reach averages for the percent shade based on the Solar Pathfinder measurements were determined for each reach and are presented in **Attachment C**.
2. Reaches defined in the field for Solar Pathfinder measurements were further divided for input into the QUAL2K model. Reach labels in the model progress from TM1 to TM10 in the downstream direction. Reach breaks in the model were created based on a review of color and infrared aerial imagery from 2005 in GIS (**Figure C-1**). Reach breaks were made at all shade influencing clearcuts, which were primarily identified in the upper watershed and specifically along reach TM02 which was divided into reaches TM4A through TM4I for input into the model. In the lower watershed, reaches TM04 and TM05 were further divided based changes in riparian canopy density and channelization due to the road.

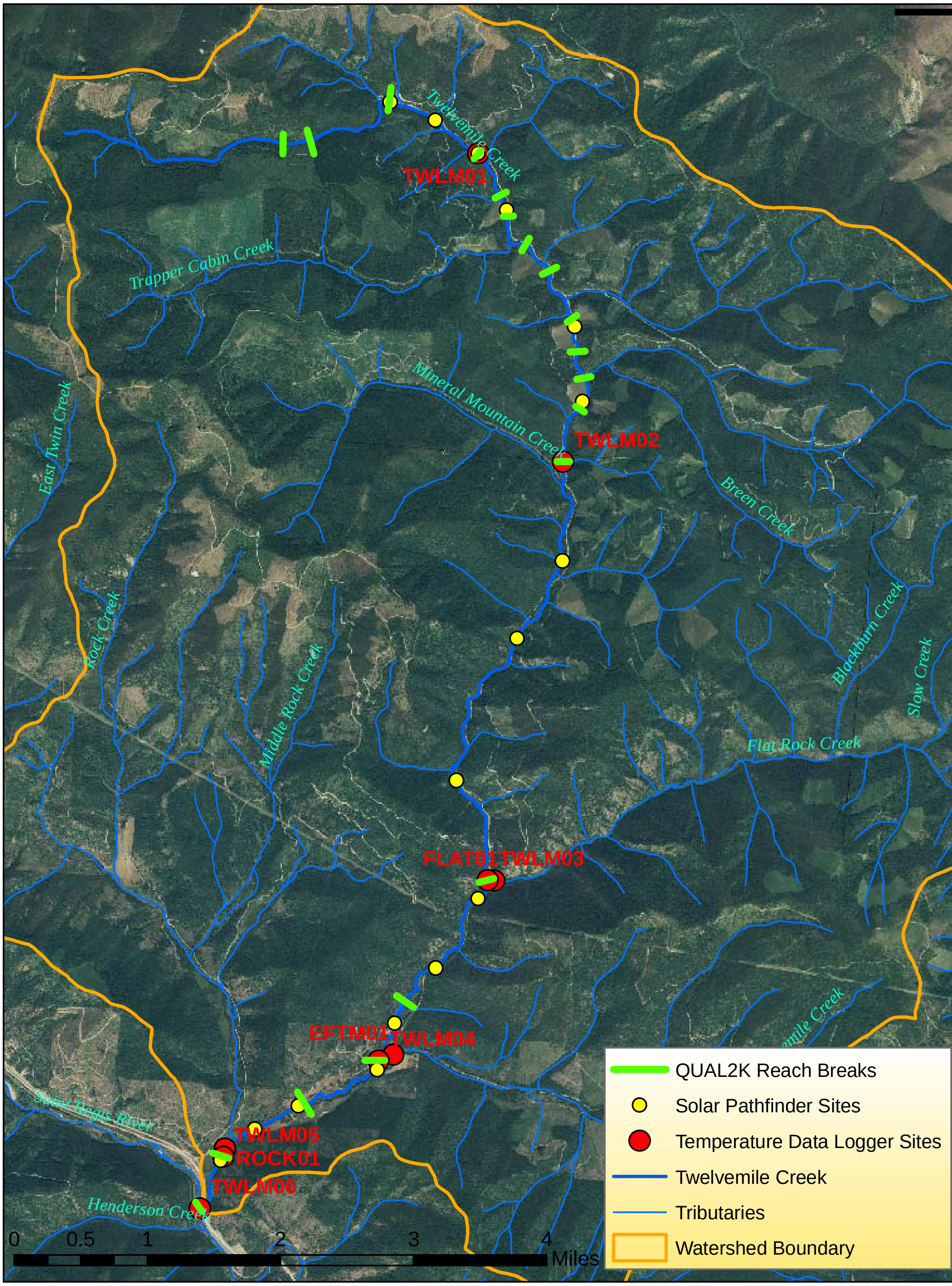

Figure C-1. Twelvemile Creek Reach Breaks and Data Collection Sites

3. Once the reach breaks were defined, the Solar Pathfinder data was reviewed to determine the appropriate measurements to apply to each reach for both existing and potential riparian shading conditions. Based on the shade data, a review of field notes, and aerial imagery, it was determined that TM01 represented reference conditions for small headwater streams within the Twelvemile Creek watershed. Thus, the average shade from this reach was assigned to other reaches which appeared to be free from timber harvest in the upper watershed. In reach TM02, all of the solar pathfinder measurements were performed at sites with clearcuts. Thus, the average results of the reach TM02 shade assessment were assigned to all of the upper reaches influenced by clearcuts. Reach TM03 was determined to represent reference conditions for mid-sized streams in semi-confined valleys with a mix of shrubs in the understory and conifers in the overstory. Shading in this reach was slightly impacted by the road, so conditions represent the potential with the continuing presence of the road. Shading from this reach was applied to impacted reaches in the lower watershed when modeling the potential to decrease stream temperatures by increasing shade. Reach TM04 was divided into two reaches based on changes in riparian vegetation density and canopy type, with the upper two Solar Pathfinder measurements representing essentially natural conditions, while there was a notable decrease in riparian vegetation density at the lower end of the reach. Reach TM05 was channelized by the road at the lower two Solar Pathfinder measurement sites, which were averaged to represent the influence of the channelization. Streamside shading along reach TM06 was determined to be in essentially natural conditions, excluding the influence of the I-90 crossing. **Table C-2** presents the reach average shade values for field defined reaches and a brief description of the reach conditions. This table also includes columns for "Existing Conditions" and "Increased Shading" that identify which shade values were assigned to the QUAL2K model reaches.

Table C-2. Twelvemile Creek Solar Pathfinder Reaches

Solar Pathfinder Reach	Reach Description	Average Daily Shade	QUAL2K Defined Reaches Assigned Shading Values based on Field Identified Reaches	
			Existing Conditions	Increased Shading
TM01	Potential reference conditions for small headwater streams	89%	TM1, TM3, TM4A, TM4C, TM4E, TMG, TM4I	TM1, TM2, TM3, TM4A-I
TM02	Clearcut conditions for small headwater streams	59%	TM2, TM4B, TM4D, TM4F, TM4H	
TM03	Potential reference conditions for mid-size streams in semi-confined valleys with some road influence, shrubs and conifers	56%	TM5	TM5
TM04 (1&2)	Potential reference conditions for mid-size streams in semi-confined valleys with shrubs and conifers	65%	TM6	TM6
TM04 (3)	Reach TM4 split to exclude lower pathfinder site where canopy density was reduced	44%	TM7	TM5
TM05 (1)	Un-channelized conditions along lower Twelvemile Creek with reduced canopy density	30%	TM8	TM5
TM05 (2&3)	Channelized conditions along lower Twelvemile Creek with reduced canopy density	22%	TM9	TM5
TM06	Typical conditions in shrub dominated valleys	52%	TM10	TM10

4. Once the existing shade was assigned to each reach in the model, additional calibration was required to account for tributary inputs and groundwater influences. Temperature data loggers on Flat Rock Creek, East Fork Twelvemile Creek, and Rock Creek were reviewed and it was determined that additional tributaries in the upper watershed would be modeled based on the temperature for Flat Rock Creek, since it was the farthest upstream tributary at which temperature data was available. Streamflow measurements and estimates were used to come up with a hydrologic balance for the model. During this process, it was observed that Twelvemile Creek is a “losing” stream from the confluence with Flat Rock Creek to the mouth (see **Attachment B**). Downstream of the East Fork Twelvemile Creek, the channel has been relocated which may be related to decreased streamflows observed during this assessment.

5. The QUAL2K model was run using the existing shade data, streamflow and stream temperature measurements at temperature data logger sites, and streamflow and temperature estimates at other identified tributaries. The model did not calibrate well with this information and under-predicted the average stream temperature at the mouth. The model was then re-calibrated by assigning the temperature data from Flat Rock Creek to the East Fork Twelvemile Creek and Rock Creek. Thus, all of the tributaries were modeled at the same temperature, which resulted in the model calibration depicted in **Figure C-2**.

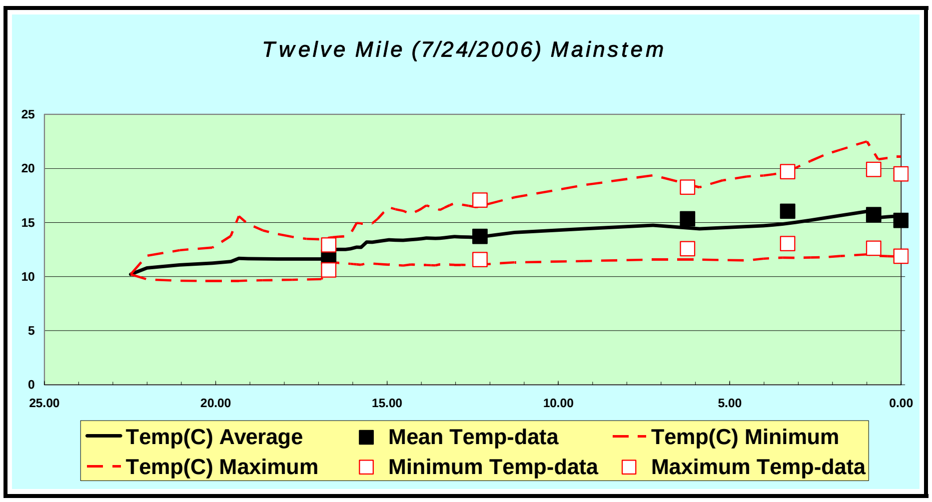

Figure C-2. QUAL2K Model Results for Twelvemile Creek with Existing Shade

6. Once stream temperatures based on existing shade was modeled, the potential to decrease stream temperatures by increasing the amount of shade was assessed. Shading values were adjusted for clearcut reaches in the upper watershed (TM2, TM4B, TM4D, TM4F, and TM4H) by assigning the average shade from TM01 (**Table C-1**). Shading values for impacted reaches in the lower watershed (TM7, TM8, and TM9) were assigned the average shade from TM03, which acknowledges the continuing presence of the road. With an increase in shade along the mainstem of Twelvemile Creek, the QUAL2K model predicted a slight reduction in stream temperatures (**Figure C-3**). Note that the spike in water temperature upstream of the first temperature data logger (**Figure C-1**), which represents a clear cut section, was removed by increasing the amount of shade in this

reach. The model also predicted that increasing the amount of shade will decrease temperatures between the first (TWLM01) and second (TWLM02) temperature data loggers, where there are several clearcuts, and between the forth (TWLM04) and fifth (TWLM05) temperature data loggers, which bracket the channelized section.

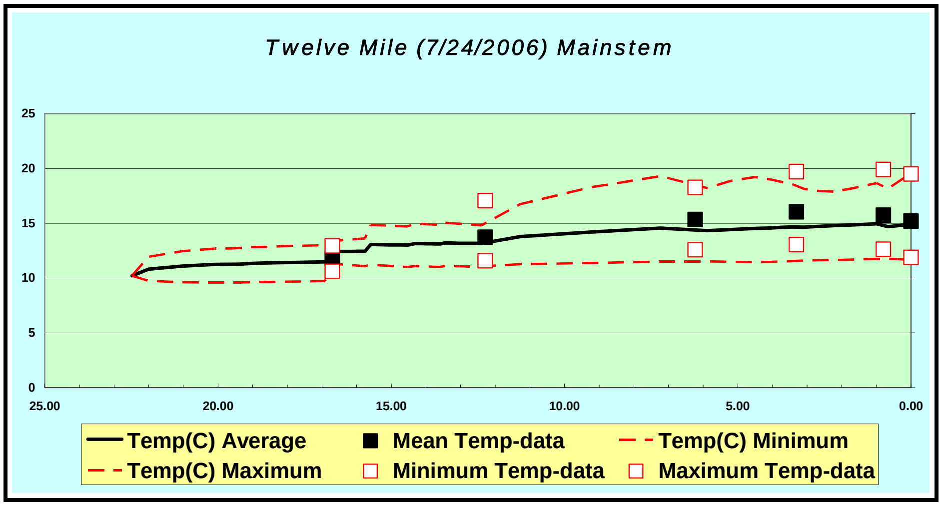

Figure C-3. QUAL2K Model Results for Twelvemile Creek with Increased Shade

7. The additional influence of timber harvest in tributary watersheds was then analyzed for the potential to affect water temperatures in Twelvemile Creek. The tributary to the north of Breen Creek was modeled using QUAL2K to determine the potential to decrease temperatures in tributary streams by increasing the amount of riparian shading. This uncalibrated model used aerial photo assessment techniques and a comparison to monitoring sites on the mainstem. The results of this exercise indicated that an approximately 5% reduction in temperature could likely be achieved in most of the headwater tributaries in the Twelvemile Creek watershed where historic clear cutting has affected streamside shading. This value, which equates to an approximately 1.8°F (1°C) reduction in tributary stream temperature, was then applied to all of the tributaries within the watershed, which resulted in a significant decease in stream temperatures along the mainstem of Twelvemile Creek (**Figure C-4**).

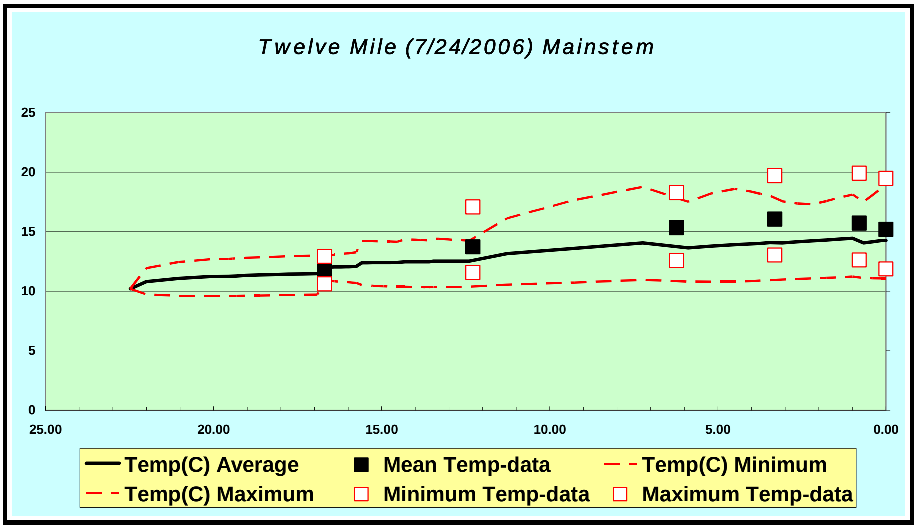

Figure C-4. QUAL2K Model Results for Twelvemile Creek with Increased Shade and Decreased Tributary Temperatures

Twelvemile Creek Modeled Temperatures Relative to Montana Standards

To evaluate the QUAL2K model results relative to Montana's water quality standards, the maximum temperatures predicted in the model scenario for increased shading and decreased tributary inputs were compared to the maximum temperatures predicted by the model for the existing shade conditions. The QUAL2K model results indicated that stream temperature could be decreased by greater than 1ºF by increasing shade (**Figure C-3**) along the mainstem of Twelvemile Creek (**Table C-3**). Additional stream temperature reductions could be achieved by decreasing temperatures on tributary streams (**Figure C-4**). This result suggests that Twelvemile Creek is exceeding Montana's water quality standard and that reduced shading resulting from anthropogenic disturbance is partially responsible for the increase in stream temperatures.

Table C-3. QUAL2K Model Results for Twelvemile Creek Relative to Montana Standards

Data Logger Site	Field Measured Data		QUAL2K Modeled "Existing Shade"		QUAL2K Modeled "Increased Shade"		Q2K Modeled "Increased Shade & Decreased Tributary Temperatures"	
	Distance (km)	Maximum Temperature (ºF)	Estimated Maximum Temperature (ºF)	Departure from Field Data (ºF)	Estimated Maximum Temperature (ºF)	Departure from "Existing Shade" Model (ºF)	Estimated Maximum Temperature (ºF)	Departure from "Existing Shade" Model (ºF)
TWLM01	16.70	55.3	56.2	0.91	55.4	-0.81	55.4	-0.81
TWLM02	12.29	62.7	61.6	-1.15	58.7	-2.92	57.6	-3.94
TWLM03	6.23	64.9	66.9	1.98	66.7	-0.13	65.8	-1.10
TWLM04	3.31	67.5	67.2	-0.21	65.4	-1.81	64.4	-2.83
TWLM05	0.80	67.8	72.5	4.65	65.6	-6.91	64.6	-7.87
TWLM06	0.00	67.1	69.9	2.86	66.7	-3.26	65.6	-4.37

Big Creek Modeled Temperatures

The following steps were taken to calibrate and run the various shading scenarios in the QUAL2K model for Big Creek:

1. Solar Pathfinder data was collected at 8 reaches in the field between each of the temperature data logger sites, with one reach upstream of the uppermost data logger on each of the three forks of Big Creek. The mainstem of Big Creek was divided into one reach, with temperature data loggers at the mouth and below the confluence of the West Fork and East Fork. The East Fork and Middle Fork were each divided into two reaches, while the West Fork was divided into three reaches. In the field, reaches were labeled BG01 through BG08 progressing in the downstream direction, with BG01 and BG02 on the Middle Fork, BG03 and BG04 on the East Fork, BG05 through BG07 on the West Fork, and BG08 on the mainstem of Big Creek. Reach averages for the percent shade based on the Solar Pathfinder measurements were determined for each reach and are presented in **Attachment C**.
2. Reaches defined in the field for Solar Pathfinder measurements were further divided for input into the QUAL2K model. Reach labels in the model progress from "Mainstem headwaters" to "Big8" in the downstream direction. For purposes of the model, the West Fork was considered the headwaters and the Middle and East forks where considered point source inputs. The mainstem of Big Creek begins at the confluence of the West and East forks. Reach breaks in the model were created based on a review of color and infrared aerial imagery from 2005 (**Figure C-5**). Reach breaks were made at all clearcuts and other observed changes in riparian canopy conditions. Additional reach breaks for the QUAL2K model include the West Fork headwaters, which was split into three reaches based on an observed timber harvest (Mainstem headwaters, Big2 and Big3). In addition, the West Fork between data logger WFBG03 and BIGC01 was identified as a short individual reach (Big6), while the mainstem of Big Creek (BG08) was divided into two reaches, since the upper half of the mainstem appeared to be in relatively natural conditions (Big7), while the lower half of the mainstem is wide and aggraded with extensive gravel bar complexes (Big 8).

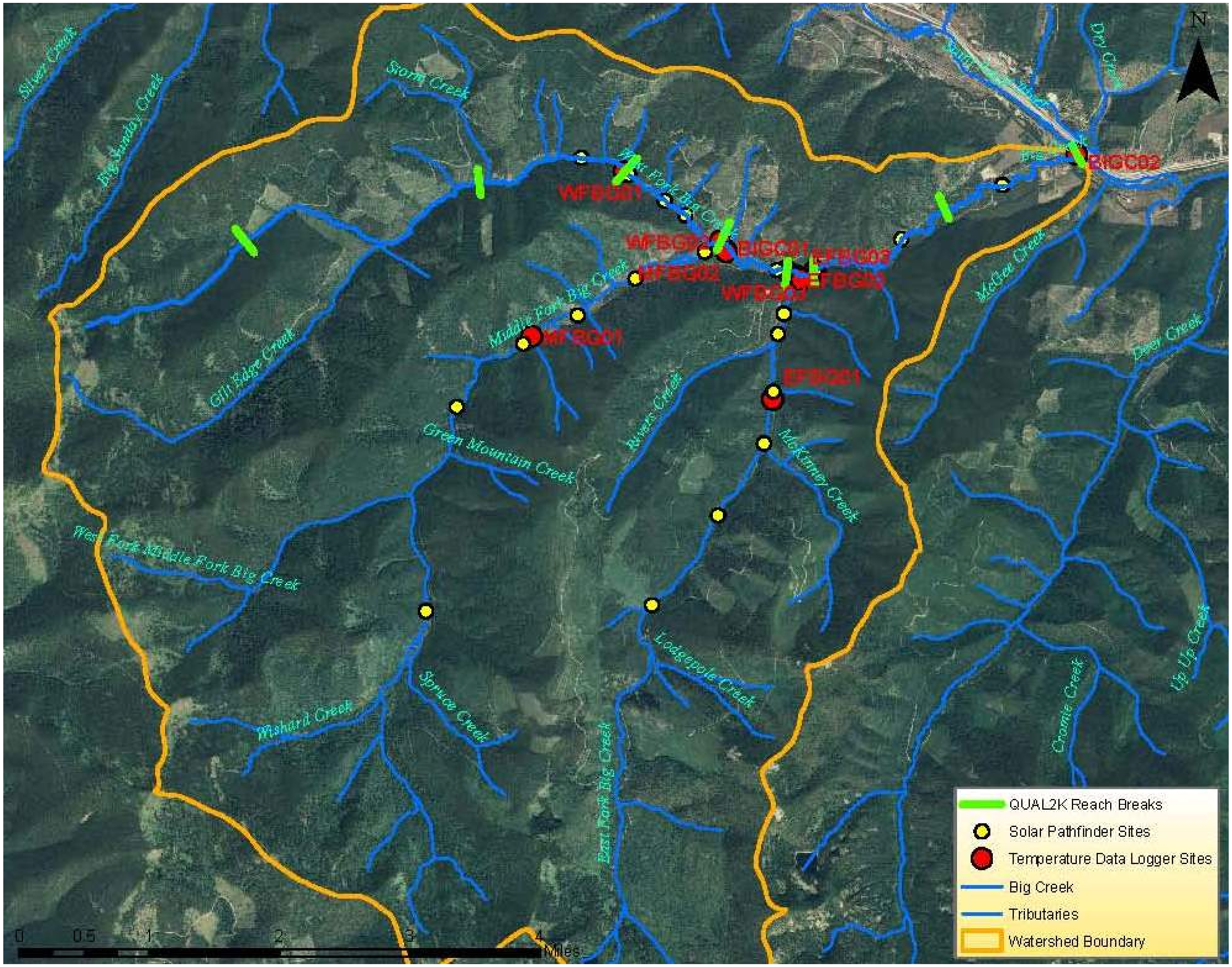

Figure C-5. Big Creek Reach Breaks and Data Collection Sites

3. Once the reach breaks were defined, Solar Pathfinder data was reviewed to determine which data should be applied to each reach for both existing and potential riparian shading conditions. Since no shade data was collected in the upper West Fork watershed, data from the upper Middle Fork (BG01) was assigned to reaches “Mainstem headwaters” and “Big2” based on a review of aerial imagery. Reference conditions for mid-sized streams in confined valleys with coniferous vegetation along the channel margin were most accurately represented by two solar pathfinder measurements in the upper East Fork (BG01) and two measurements in the upper Middle Fork (BG03). While selective timber harvest of large trees from these sites historically was observed at these sites, the overall amount of shading appeared to most closely represent reference conditions. The reference value derived from these four solar pathfinder measurements was assigned to the West Fork reaches upstream of the confluence with the Middle Fork (Mainstem headwaters, Big 2, Big3, and Big 4) when modeling the potential for increased shading. For the mainstem of Big Creek, reference conditions were developed based on the upper two solar pathfinder measurements on Big Creek. Shade from this reach was assigned to Big5, Big6, and Big8 when modeling potential shading. Existing conditions along Big7 were not altered, since the system appeared to be in a relatively natural state. **Table C-4** presents the reach average shade, provides a brief description of reach conditions, and identifies which shade values were assigned in QUAL2K.

Table C-4. Big Creek Solar Pathfinder Reaches

Field Identified Reaches	Reach Description	Average Daily Shade	QUAL2K Defined Reaches Assigned Shading Values based on Field Identified Reaches	
			Existing Conditions	Increased Shading
BG01	Upper Middle Fork, confined, mid-size stream in conifers (big cedars) with some logging, road impacts at lowest site	62%	Mainstem headwaters, Big 2	
BG02	Lower Middle Fork, signs of historic removal of cedars from valley bottom, site of recent timber harvest, streambed was dry during site visits in August & September	18%	not included directly in the model*	
BG03	Upper East Fork, confined, mid-size stream in conifers (big cedars) with some logging	63%	not included directly in the model*	
BG04	Lower East Fork, likely historic harvest of valley bottoms	36%	not included directly in the model*	
BG05	Upper West Fork, shrub meadow with conifers on hillslopes, historic road, likely historic harvest	21%	Big 3	
BG06	West Fork above Middle Fork, shrubs and conifers, beaver impacts at lower end	42%	Big 4	
BG07	West Fork above East Fork, typical shrub meadow in area with beaver influence	23%	Big 5, 6	
BG08 (1&2)	Big Creek mainstem in area dominated by conifers, appears to be approaching natural conditions for the size of the stream	52%	Big 7	Big 5, 6,7, 8
BG08 (3)	Big Creek mainstem in area dominated by cottonwoods, with overwidened channel and exposed gravel bars	24%	Big 8	
BG01 (1&2) & BG03 (2&3)	Reference conditions for confined, mid-size streams in conifers (big cedars) with some logging, based on BG01-1,2 & BG03-2,3	71%		Mainstem headwaters, Big 2, 3, 4

* Riparian shade data for the East Fork and Middle Fork, which includes field defined reaches BG02, BG03 and BG04, was not included directly in the modeled since these tributaries were considered "point sources" (see bullet #7).

4. The model was first run with 0% shade between the hours of 6am and 5pm (**Figure C-6**). This was done to assess potential groundwater inputs at temperature data logger WFBG03. This area was of interest since there was a large beaver complex upstream of site WFBG02 that greatly reduced streamflow. In addition, the Middle Fork was dewatered between the upper (MFBG01) and lower (MFBG02) temperature data loggers and groundwater upwelling was observed at the lower data logger (WFBG03). When the hydrologic balance was performed (see **Attachment B**), it appeared that all the water "lost" from the West and Middle forks upstream of their confluences was "gained" by the West Fork at site WFBG03 just upstream of the confluence with the East Fork and the start of the Big Creek mainstem. This large upwelling of groundwater led to decreased stream temperatures at data loggers WFBG03 and BIGC01 (points 3 and 4 on **Figure C-6**). When the model was run with existing stream temperatures and no shade, the results supported the hypothesis that stream temperature at these two sites was primarily controlled by groundwater upwelling.

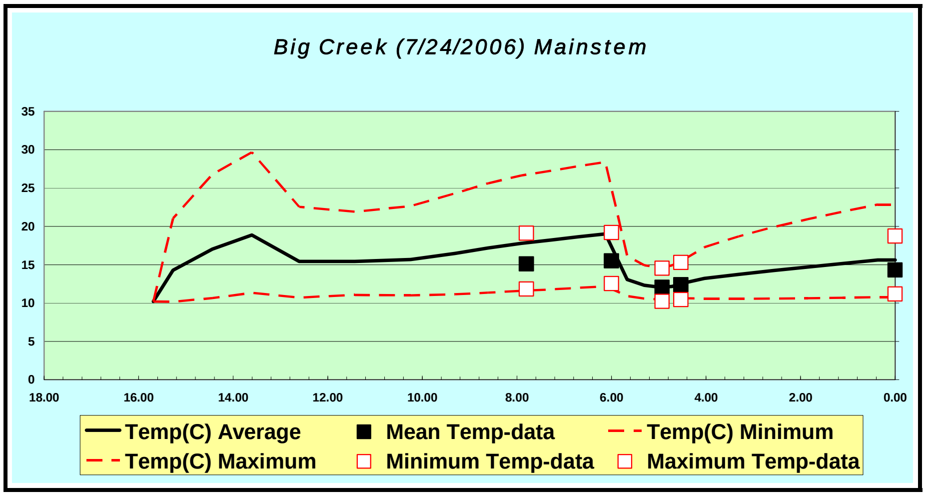

Figure C-6. QUAL2K Model Results for Big Creek with No Shade

5. When the QUAL2K model was run with the existing shade, the results provide further support for the hypothesis that stream temperature at data loggers WFBG03 and BIGC01 was primarily controlled by groundwater upwelling, while riparian shading plays an important role in stream temperatures in the West Fork Big Creek (**Figure C-7**). It is worth noting that the mean daily stream temperature increased 1.9°C (3.5°F) on July 24, 2006, between the headwaters of the Big Creek mainstem at the confluence with the West and East Forks and the mouth, which is a distance of approximately 4.5 miles. In addition, it was observed that Big Creek was a "losing" stream between the upper (BIGC01) and lower (BIGC02) data loggers and it was noted in the field that this appeared to occur in an over-widened area with aggraded gravel bar conditions along the lowermost 2 miles of Big Creek. It is unclear what process led to the existing aggraded conditions, though the 1910 fires, historic timber harvest, the presence of a large bridge, or a combination of all of these factors may have led to the aggradation.

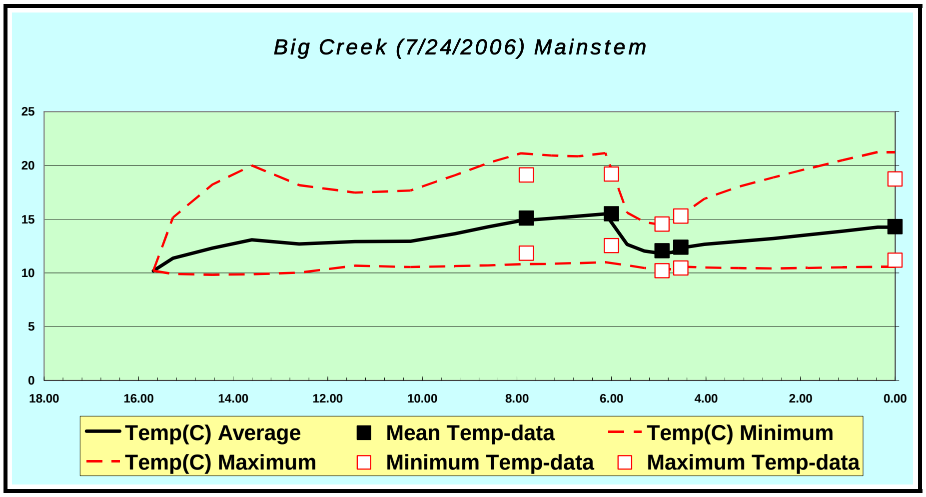

Figure C-7. QUAL2K Model Results for Big Creek with Existing Shade

6. The potential for increased shade was then modeled, with reaches "Mainstem headwaters", Big2, Big3, and Big4 modeled based on reference data from BG01 and

BG03, and shade along the lower West Fork (Big5 and Big6) and the mainstem of Big Creek (Big7 and Big8) modeled based on shade for Big7 (**Figure C-8**). The model predicated that temperatures on the West Fork could be lowered by increasing the amount of shading, and that this would lead to a slight decrease in stream temperatures along the mainstem of Big Creek. Increased shading on the Middle Fork is not likely to influence temperatures at this time since the stream becomes dewatered in mid-summer, though the anthropogenic role in this phenomenon is unknown. Temperatures in the East Fork influence the Big Creek mainstem, though the existing data and the model suggest that relatively cool water due to groundwater upwelling is the major influence on water temperature at the upper end of the mainstem of Big Creek. Temperatures then increase in the downstream direction, which is likely related to a loss of shade in the aggraded gravel-bar area, along with a loss of streamflow to groundwater infiltration.

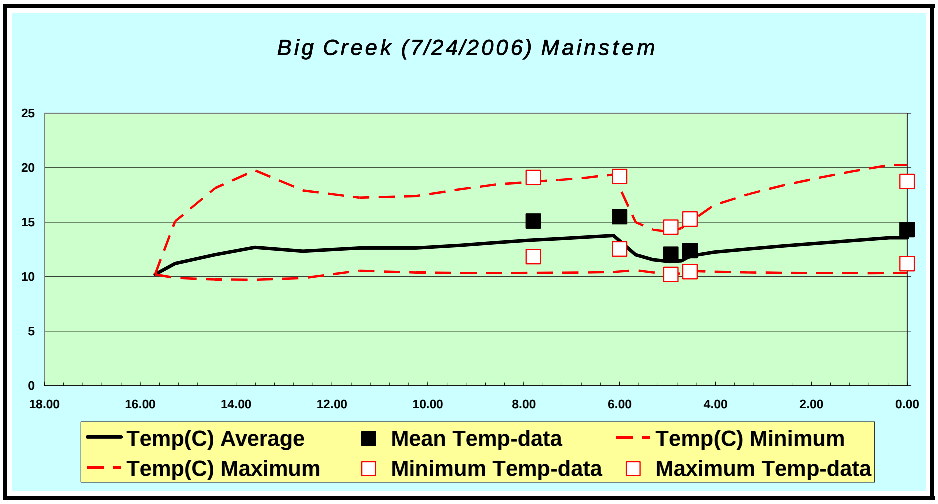

Figure C-8. QUAL2K Model Results for Big Creek with Increased Shade

7. The additional influence of timber harvest in tributary watersheds was then analyzed for the potential to affect water temperatures in Big Creek. As in Twelvemile Creek, it was estimated that an approximately 1.8°F (1°C) reduction in tributary stream temperature could be achieved through an increase in streamside shading. This value was applied to all of the modeled tributaries within the watershed, which include the Middle Fork Big Creek, East Fork Big Creek, and Gilt Edge Creek, which is a tributary of the West Fork Big Creek. This resulted in a slight decease in stream temperatures along the mainstem of Big Creek (**Figure C-9**).

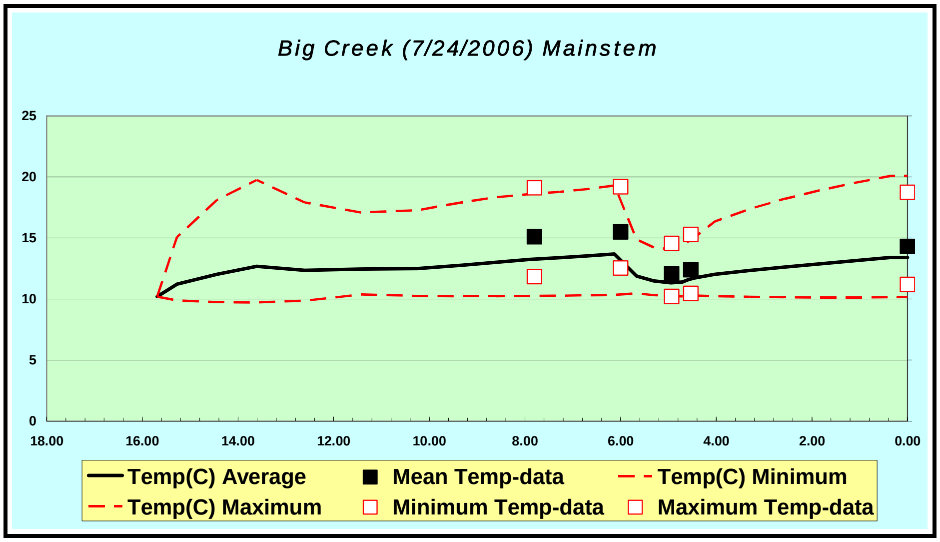

Figure C-9. QUAL2K Model Results for Big Creek with Increased Shade and Decreased Tributary Temperatures

Big Creek Modeled Temperatures Relative to Montana Standards

To evaluate the QUAL2K model results relative to Montana's water quality standards, the maximum temperatures predicted in the model scenario for increased shading and decreased tributary inputs were compared to the maximum temperatures predicted by the model for the existing shade conditions. The QUAL2K model results indicated that stream temperature along the mainstem of Big Creek could be decreased by greater than 1ºF by increasing the amount of shade (**Figure C-8** and **Table C-5**). A slight additional reduction in stream temperature could be achieved by decreasing temperatures on tributary streams (**Figure C-9**). This result suggests that Big Creek is exceeding Montana's water quality standard and that reduced shading resulting from anthropogenic disturbance is partially responsible for the increase in stream temperatures. Warm water inputs from the East Fork and West Fork are identified as sources of increased stream temperatures to Big Creek.

Table C-5. QUAL2K Model Results for Big Creek Relative to Montana Standards

Data Logger Site	Field Measured Data		QUAL2K Modeled "Existing Shade"		QUAL2K Modeled "Increased Shade"		Q2K Modeled "Increased Shade & Decreased Tributary Temperatures"	
	Distance (km)	Maximum Temperature (ºF)	Estimated Maximum Temperature (ºF)	Departure from Field Data (ºF)	Estimated Maximum Temperature (ºF)	Departure from "Existing Shade" Model (ºF)	Estimated Maximum Temperature (ºF)	Departure from "Existing Shade" Model (ºF)
WFB01	7.80	66.4	70.0	3.64	65.6	-4.39	65.5	-4.57
WFB02	6.00	66.5	70.1	3.54	66.9	-3.20	66.7	-3.34
WFB03	4.93	58.2	58.1	-0.12	57.4	-0.63	57.3	-0.73
BIG01	4.53	59.5	59.4	-0.10	58.8	-0.60	58.5	-0.93
BIG02	0.00	65.7	70.2	4.51	68.4	-1.82	68.1	-2.12

ST. REGIS RIVER CANOPY DENSITY ASSESSMENT

The canopy density along the St. Regis River was initially assessed using 2000 vintage aerial photographs (1:15,840 scale) and a mirror stereoscope in 2003. This assessment is summarized in Section 7.1.2 of the *Draft St. Regis Watershed Water Quality Restoration Plan: Sediment and Temperature TMDLs* (MDEQ 2006b), with a more detailed discussion provided in **Appendix K**. During the aerial assessment, canopy density was determined at the reach scale. In addition to the reach scale measurements, canopy density of specific riparian stands was noted on hard copy aerial photos at twenty-five sites. Canopy cover was field verified in 2003 utilizing a spherical densiometer at seven of these sites in which aerial photo interpretation ranged from 35-75% canopy cover. The purpose of field verification was to assess the results of the aerial assessment within riparian stands for which the canopy density was specifically noted. Canopy cover measurements using a spherical densiometer averaged 11% higher than the aerial photo interpretation with the mirror stereoscope indicated. In 2006, canopy density was field verified at an additional twelve sites to provide further support for the aerial photograph assessment.

Densiometer Measurements

Canopy density was assessed with a spherical densiometer at twelve sites along the St. Regis River on August 15th and 16th, 2006. These sites were assessed to confirm the accuracy of the aerial photograph assessment for canopy density along the St. Regis River. Sites were selected from the twenty-five sites for which canopy density was specifically noted in 2003. Sites were selected to span a range of canopy densities (25%-85%), while also evaluating the canopy density of different types of riparian vegetation (cottonwood vs. conifer). Densiometer measurements ranged from 2% below the aerial assessment measurements to 14% above the aerial assessment measurements in the 2006 assessment (**Table C-6**). Densiometer measurements at these twelve sites indicated a greater percentage of canopy density than in the aerial assessment by an average of 4%. Based on the results of ground truthing performed in 2003 and 2006, it is estimated that actual canopy densities average between 4% and 11% greater than the aerial assessment indicates. Field data from the 2006 assessment is presented in **Attachment E**.

Table C-6. Canopy Density Comparison between Aerial Assessment and Densiometer Measurements

AERIAL ASSESSMENT		DENSIOMETER	
Reach	**Canopy Density (%)**	**Site ID**	**Canopy Density (%)**
1	75	**SR 1.0-1**	75
1.7	55	**SR 1.7-1**	62
1.9	55	**SR 1.9 -1**	63
4.1	45	**SR 4.1-1**	43
5	50	**SR 5.0-1**	57
5.3	45	**SR 5.3-1**	47
5.4	35	**SR 5.4-1**	34
5.5	35	**SR 5.5-1**	49
5.7	25	**SR 5.7-1**	28
7.5	75	**SR 7.5-1**	88
7.5	55	**SR 7.5-2**	53
7.7	85	**SR 7.7-1**	84

REFERENCES

MDEQ. 2006a. Field Monitoring and Temperature Modeling Sampling and Analysis Plan for the 2006 Field Season. Prepared by PBS&J, Helena, Montana: PBS&J.

MDEQ. 2006b. Draft St. Regis Watershed Water Quality Restoration Plan: Sediment and Temperature TMDLs. Prepared by PBS&J.

U.S. Fish and Wildlife Service. 1998. A Framework to Assist in Making Endangered Species Act Determinations of Effect for Individual or Grouped Actions at the Bull Trout Subpopulation Watershed Scale.

ATTACHMENT A
2006 TEMPERATURE DATA SUMMARY

St. Regis TMDL Planning Area

Big Creek watershed

Site ID	Site Name	Lat	Long	Start Date	Stop date	Seasonal Maximum		Seasonal Minimum		Seasonal Max □T		Seasonal Maximum 7-Day Averages			
						Date	Value	Date	Value	Date	Value	Date	Daily Maximum	Daily Minimum	□ T
WFBG01	530220- West fork Big Creek upper site	47.37182	115.4597	07/11/06	09/12/06	07/24/06	66.4	09/02/06	44.4	07/21/06	14.1	07/25/06	65.7	52.2	13.5
WFBG02	530250-West fork above Middle fork "notch"	47.36496	115.44315	07/11/06	09/12/06	07/23/06	66.8	09/02/06	45.1	09/11/06	14.2	07/25/06	66.0	53.6	12.5
WFBG03	584786-West fork at mouth, above east fork	47.36219	115.43198	07/11/06	09/11/06	07/24/06	58.2	09/11/06	45.9	07/14/06	10.3	07/23/06	57.7	49.6	8.1
MFBG01	530247-Middle Fork-upper site at upstream end of meadow	47.35277	115.47286	07/11/06	09/11/06	07/24/06	63.1	09/01/06	42.1	08/14/06	11.7	07/25/06	62.1	51.2	10.9
MFBG02	584807-Middle fork above West fork	47.36379	115.44207	07/11/06	09/12/06	07/24/06	65.2	09/11/06	46.9	07/19/06	13.8	07/24/06	64.5	52.6	11.9
EFBG01	530225-EF Big Creek	47.34785	115.43278	07/11/06	09/12/06	07/23/06	61.7	09/01/06	42.3	07/14/06	9.8	07/25/06	60.7	52.0	8.7
EFBG02	530206-East Fork above mouth	47.3617	115.43031	07/11/06	09/11/06	07/24/06	60.8	09/02/06	44.6	07/15/06	9.2	07/25/06	60.2	51.7	8.5
EFBG03	530219-EF Big Creek, lower most fork	47.36141	115.42957	07/11/06	09/11/06	07/24/06	62.3	09/02/06	45.5	07/21/06	10.1	07/25/06	61.5	51.9	9.6
BIGC01	530232-Big Creek below E and W forks	47.36247	115.42743	07/11/06	09/11/06	07/24/06	59.5	09/02/06	45.5	07/14/06	10.1	07/25/06	59.0	50.3	8.7
BIGC02	530209-Big Creek by railroad bridge	47.37752	115.38597	07/11/06	09/11/06	07/24/06	65.8	07/31/06	48.0	07/21/06	14.1	07/25/06	65.0	51.5	13.5

Big Creek watershed

Site ID	Site Name	Days > 50 F	Days > 59 F	Days > 70 F	Hours > 50 F	Hours > 59 F	Hours > 70 F	Warmest day of 7-day max			Agency
								Date	Maximum	Minimum	
WFBG01	530220- West fork Big Creek upper site	64	34	0	1204.5	199.5	0.0	07/23/06	66.4	53.3	DEQ
WFBG02	530250-West fork above Middle fork "notch"	64	54	0	1346.0	329.5	0.0	07/23/06	66.8	54.6	DEQ
WFBG03	584786-West fork at mouth, above east fork	62	0	0	710.0	0.0	0.0	07/23/06	58.2	50.4	DEQ
MFBG01	530247-Middle Fork-upper site at upstream end of meadow	63	14	0	944.0	55.5	0.0	07/24/06	63.1	52.1	DEQ
MFBG02	584807-Middle fork above West fork	63	21	0	1171.0	137.5	0.0	07/23/06	65.2	53.6	DEQ
EFBG01	530225-EF Big Creek	64	9	0	1059.5	47.5	0.0	07/23/06	61.7	53.2	DEQ
EFBG02	530206-East Fork above mouth	63	7	0	972.5	28.0	0.0	07/24/06	60.8	52.7	DEQ
EFBG03	530219-EF Big Creek, lower most fork	63	11	0	1072.0	44.5	0.0	07/24/06	62.3	52.8	DEQ
BIGC01	530232-Big Creek below E and W forks	63	2	0	762.0	4.5	0.0	07/23/06	59.5	50.8	DEQ
BIGC02	530209-Big Creek by railroad bridge	63	46	0	1372.5	244.0	0.0	07/24/06	65.8	52.2	DEQ

Twelvemile Creek watershed

Site ID	Site Name	Lat	Long	Start Date	Stop date	Seasonal Maximum		Seasonal Minimum		Seasonal Max □T		Seasonal Maximum 7-Day Averages			
						Date	Value	Date	Value	Date	Value	Date	Daily Maximum	Daily Minimum	□ T
TWLM01	530216-Twelvemile Cr. above Trapper Cabin @ mile marker 8	47.4664	115.25957	07/12/06	09/10/06	07/23/06	55.6	09/01/06	41.9	08/06/06	5.0	07/25/06	54.5	50.1	4.4
TWLM02	530238-Twelvemile Cr. above Mineral Mt. Cr.	47.43311	115.24282	07/12/06	09/10/06	07/24/06	62.7	09/01/06	41.4	08/06/06	10.9	07/25/06	61.8	51.9	9.9
TWLM03	530231-Twelvemile Cr. above Flatrock	47.38748	115.24949	07/12/06	09/10/06	07/23/06	65.5	09/01/06	42.9	07/21/06	11.6	07/25/06	64.2	53.5	10.8
TWLM04	584847-Twelvemile Creek above east fork	47.36701	115.26478	07/12/06	09/10/06	07/23/06	67.8	09/01/06	42.7	08/06/06	13.5	07/25/06	66.6	54.1	12.5
TWLM05	530228-Twelvemile Cr. Upstream of Rock Cr.	47.3853	115.2886	07/12/06	09/10/06	07/23/06	68.1	09/01/06	43.0	09/02/06	15.3	07/25/06	67.1	53.4	13.6
TWLM06	530237-Twelvemile at mouth	47.34949	115.29169	07/12/06	09/10/06	07/23/06	67.7	09/01/06	43.9	07/21/06	15.3	07/25/06	66.7	52.3	14.3
FLAT01	584732-Flat Rock Cr. Above bridge under moss covered log	47.3875	115.24843	07/12/06	09/10/06	07/24/06	61.6	09/01/06	42.6	07/17/06	9.8	07/25/06	60.8	51.8	9.0
EFTM01	530251-East fork Twelvemile	47.36773	115.26252	07/12/06	09/10/06	07/15/06	45.2	09/02/06	41.9	09/02/06	2.5	07/25/06	44.9	43.1	1.9
ROCK01	530236-Rock Creek mouth	47.35618	115.28838	07/12/06	09/10/06	07/15/06	55.4	08/03/06	44.0	08/14/06	10.6	07/25/06	54.9	44.9	10.0

Twelvemile Creek watershed

Site ID	Site Name	Days > 50 F	Days > 59 F	Days > 70 F	Hours > 50 F	Hours > 59 F	Hours > 70 F	Warmest day of 7-day max			Agency
								Date	Maximum	Minimum	
TWLM01	530216-Twelvemile Cr. above Trapper Cabin @ mile marker 8	45	0	0	495.5	0.0	0.0	07/23/06	55.6	50.8	DEQ
TWLM02	530238-Twelvemile Cr. above Mineral Mt. Cr.	61	10	0	940.5	40.5	0.0	07/23/06	62.7	53.1	DEQ
TWLM03	530231-Twelvemile Cr. above Flatrock	61	24	0	1213.5	175.0	0.0	07/23/06	65.5	54.7	DEQ
TWLM04	584847-Twelvemile Creek above east fork	61	42	0	1240.0	293.0	0.0	07/23/06	67.8	55.2	DEQ
TWLM05	530228-Twelvemile Cr. Upstream of Rock Cr.	61	50	0	1214.5	316.0	0.0	07/23/06	68.1	54.7	DEQ
TWLM06	530237-Twelvemile at mouth	61	43	0	1227.0	292.0	0.0	07/23/06	67.7	53.7	DEQ
FLAT01	584732-Flat Rock Cr. Above bridge under moss covered log	61	8	0	1032.5	40.5	0.0	07/23/06	61.6	52.9	DEQ
EFTM01	530251-East fork Twelvemile	0	0	0	0.0	0.0	0.0	07/22/06	44.9	43.0	DEQ
ROCK01	530236-Rock Creek mouth	61	0	0	425.0	0.0	0.0	07/23/06	55.2	45.4	DEQ

ATTACHMENT B
STREAMFLOW DATA

St. Regis TMDL Planning Area

Stream Segment	Site	Site Name	Date	Flow (cfs)	Flow (cms)	Temperature (ºC)	Time
Twelvemile Creek	upstream of Trapper Cabin Cr	TWLM01	8/17/07	2.50	0.071	9.0	7:45
Twelvemile Creek	upstream of Mineral Mt Cr	TWLM02	8/17/07	7.84	0.222	9.9	9:15
Twelvemile Creek	upstream of Flat Rock Creek	TWLM03	8/17/07	8.08	0.229	11.3	11:15
Twelvemile Creek	upstream of East Fork Twelvemile Creek	TWLM04	8/17/07	13.00	0.368	12.4	12:00
Twelvemile Creek	upstream of Rock Creek	TWLM05	8/17/07	10.37	0.294	14.0	13:15
Twelvemile Creek	at mouth	TWLM06	8/17/07	10.27	0.291	12.8	13:45
Flat Rock Creek	at mouth	FLAT01	8/17/07	5.83	0.1651	10.2	10:45
East Fork Twelvemile Cr	at mouth	EFTM01	8/17/07	1.06	0.030	6.6	11:45
Rock Creek	at mouth	ROCK01	8/17/07	3.92	0.111	11.5	13:00
tributary		Trib 1	8/17/07	0.2*	0.01	9.3	8:15
tributary	Trapper Cabin Creek	Trib 2	8/17/07	4.0*	0.11	8.9	8:30
tributary	tributary north of Breen Creek	Trib 3	8/17/07	0.4*	0.01	9.7	8:45
tributary	Mineral Mountain Creek	Trib 4	8/17/07	2.0*	0.06	9.5	9:45
tributary		Trib 5	8/17/07	0.4*	0.01	8.3	10:15
tributary		Trib 6	8/17/07	0.8*	0.02	8.6	10:30

* Flow Visually Estimated

Stream Segment	Site	Site Name	Date	Flow (cfs)	Flow (cms)	Temperature (ºC)	Time
Big Creek	downstream of confluence of West & East fks	BIGC01	8/14/07	17.05	0.48	12.9	15:45
Big Creek	at mouth	BIGC02	8/14/07	8.40	0.24	15.8	18:45
East Fork Big Creek	upper	EFBG01	8/14/07	3.88	0.11	13.1	18:00
East Fork Big Creek	at mouth - upstream fork	EFBG02	8/14/07	2.29	0.06	12.3	14:30
East Fork Big Creek	at mouth - downstream fork	EFBG03	8/14/07	1.10	0.03	12.6	15:00
West Fork Big Creek	upper	WFBG01	8/14/07	4.20	0.12	10.6	11:15
West Fork Big Creek	upstream of Middle Fork confluence	WFBG02	8/14/07	1.70	0.05	12.9	12:45
West Fork Big Creek	at mouth	WFBG03	8/14/07	13.91	0.39	12.0	14:15
Middle Fork Big Creek	upper	MFBG01	8/14/07	3.14	0.09	14.5	17:00
Middle Fork Big Creek	at mouth	MFBG02	8/14/07	0.57	0.02	10.9	12:30

ATTACHMENT C
SOLAR PATHFINDER DATA

St. Regis TMDL Planning Area

Twelvemile Creek

Reach	Section	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	Site
	Potential	**3**	**5**	**8**	**10**	**12**	**12**	**12**	**12**	**10**	**8**	**5**	**3**	**Average**
TM01-1	Upstream	3	5	6	2	12	12	12	12	10	8	5	3	90
TM01-2	Middle	3	5	7	6	10	12	11	12	10	8	5	3	92
TM01-3	Downstream	3	5	7	9	9	9	9	10	9	8	5	3	86
TM01	**Average %**	**100%**	**100%**	**83%**	**57%**	**86%**	**92%**	**89%**	**94%**	**97%**	**100%**	**100%**	**100%**	**89%**
TM02-1	Upstream	3	5	7	9	1	6	2	0	7	7	5	3	55
TM02-2	Middle	3	5	4	10	12	9	1	6	7	8	5	3	73
TM02-3	Downstream	3	5	8	9	9	3	0	0	0	5	5	3	50
TM02	**Average %**	**100%**	**100%**	**79%**	**93%**	**61%**	**50%**	**8%**	**17%**	**47%**	**83%**	**100%**	**100%**	**59%**
TM03-1c	Upstream center	3	5	8	7	0	0	0	2	10	8	5	3	51
TM03-1l	Upstream left	3	5	8	5	0	0	0	0	8	8	5	3	45
TM03-1r	Upstream right	3	5	7	3	0	0	0	11	10	8	5	3	55
TM03-2c	Middle center	3	5	8	10	11	2	3	0	8	8	5	3	66
TM03-2l	Middle left	3	5	8	10	12	6	4	0	3	7	5	3	66
TM03-2r	Middle right	3	5	7	9	8	3	0	6	10	8	5	3	67
TM03-3c	Downstream center	3	5	5	3	0	0	0	9	9	8	5	3	50
TM03-3l	Downstream left	3	5	6	5	2	0	0	8	8	8	5	3	53
TM03-3r	Downstream right	3	5	4	0	0	0	3	11	9	8	5	3	51
TM03	**Average %**	**100%**	**100%**	**85%**	**58%**	**31%**	**10%**	**9%**	**44%**	**83%**	**99%**	**100%**	**100%**	**56%**
TM04-1c	Upstream center	3	5	8	9	9	6	7	0	0	3	4	3	57
TM04-1l	Upstream left	3	5	8	9	10	9	11	7	1	0	2	3	68
TM04-1r	Upstream right	3	5	7	7	8	5	5	0	0	3	5	3	51
TM04-2c	Middle center	3	5	8	9	8	8	4	2	8	8	4	3	70
TM04-2l	Middle left	3	5	8	9	6	8	4	8	9	8	4	3	75
TM04-2r	Middle right	3	5	8	9	9	9	6	0	3	7	4	3	66
TM04-3c	Downstream center	3	4	2	0	0	11	9	0	5	4	3	1	42
TM04-3l	Downstream left	3	4	6	2	3	7	11	2	3	4	4	1	50
TM04-3r	Downstream right	3	2	0	0	5	12	1	0	5	5	4	2	39
TM04	**Average %**	**100%**	**89%**	**76%**	**60%**	**54%**	**69%**	**54%**	**18%**	**38%**	**58%**	**76%**	**81%**	**58%**
TM05-1c	Upstream center	3	5	8	7	0	0	0	0	0	0	0	2	25
TM05-1l	Upstream left	3	5	7	9	11	8	1	0	0	0	0	1	45
TM05-1r	Upstream right	3	5	3	5	0	0	0	0	0	0	1	2	19
TM05-2c	Middle center	3	2	0	0	0	0	0	1	0	0	0	1	7
TM05-2l	Middle left	3	4	0	0	0	0	0	3	0	0	0	1	11
TM05-2r	Middle right	2	1	0	0	0	0	0	0	0	0	0	2	5
TM05-3c	Downstream center	2	5	8	9	0	5	0	0	0	0	2	2	33
TM05-3l	Downstream left	3	5	8	10	3	1	7	0	0	0	1	2	40
TM05-3r	Downstream right	3	4	6	9	1	5	0	0	0	0	2	3	33
TM05	**Average %**	**93%**	**80%**	**56%**	**54%**	**14%**	**18%**	**7%**	**4%**	**0%**	**0%**	**13%**	**59%**	**24%**
TM06-1c	Middle center	3	5	8	10	9	11	3	0	0	2	2	1	54
TM06-1l	Middle left	3	5	8	10	8	8	6	0	0	0	3	1	52
TM06-1r	Middle right	3	5	8	8	10	7	0	0	1	6	1	2	51
TM06	**Average %**	**100%**	**100%**	**100%**	**93%**	**75%**	**72%**	**25%**	**0%**	**3%**	**33%**	**40%**	**44%**	**52%**

Big Creek

Reach	Section	6:00 AM	7:00 AM	8:00 AM	9:00 AM	10:00 AM	11:00 AM	12:00 PM	1:00 PM	2:00 PM	3:00 PM	4:00 PM	5:00 PM	Site
	Potential	**3**	**5**	**8**	**10**	**12**	**12**	**12**	**12**	**10**	**8**	**5**	**3**	**Average**
BG01-1	Upstream	3	5	8	10	3	2	0	7	10	4	5	3	60
BG01-2c	Middle center	3	5	8	10	12	12	8	0	4	6	5	3	76
BG01-2l	Middle left	3	5	8	10	12	12	4	2	2	7	5	3	73
BG01-2r	Middle right	3	5	8	10	12	12	12	3	4	5	5	3	82
BG01-3	Downstream	3	1	0	0	0	1	4	3	0	0	4	3	19
BG01	**Average %**	**100%**	**84%**	**80%**	**80%**	**65%**	**65%**	**47%**	**25%**	**40%**	**55%**	**96%**	**100%**	**62%**
BG02-1c	Upstream center	3	2	0	0	0	0	0	0	0	0	0	2	7
BG02-2l	Upstream left	3	2	1	0	0	0	0	0	0	0	0	3	9
BG02-2r	Upstream right	3	2	1	1	0	0	0	0	0	0	0	2	9
BG02-2	Middle	3	5	4	5	0	4	0	0	0	0	0	2	23
BG02-3	Downstream	2	0	0	1	7	11	1	8	9	3	0	1	43
BG02	**Average %**	**93%**	**44%**	**15%**	**14%**	**12%**	**25%**	**2%**	**13%**	**18%**	**8%**	**0%**	**67%**	**18%**
BG03-1	Upstream	3	5	8	7	8	0	1	2	10	7	4	3	58
BG03-2	Middle	3	5	8	9	11	9	1	0	0	3	5	3	57
BG03-3	Downstream	3	5	7	10	12	10	0	9	3	8	5	3	75
BG03	**Average %**	**100%**	**100%**	**96%**	**87%**	**86%**	**53%**	**6%**	**31%**	**43%**	**75%**	**93%**	**100%**	**63%**
BG04-1	Upstream	3	5	8	9	3	2	0	0	0	6	5	3	44
BG04-2	Middle	3	5	3	9	11	0	0	7	0	0	3	3	44
BG04-3	Downstream	3	5	2	0	0	0	0	0	0	3	3	3	19
BG04	**Average %**	**100%**	**100%**	**54%**	**60%**	**39%**	**6%**	**0%**	**19%**	**0%**	**38%**	**73%**	**100%**	**36%**
BG05-1	Upstream	2	0	0	0	6	6	5	0	0	0	1	3	23
BG05-2	Middle	2	0	0	0	0	0	0	4	10	7	4	1	28
BG05-3	Downstream	2	0	0	5	0	0	0	0	0	0	1	3	11
BG05	**Average %**	**67%**	**0%**	**0%**	**17%**	**17%**	**17%**	**14%**	**11%**	**33%**	**29%**	**40%**	**78%**	**21%**
BG06-1	Upstream	3	4	4	0	0	8	9	11	9	8	5	3	64
BG06-2	Middle	3	4	7	2	0	0	0	1	9	8	5	3	42
BG06-3	Downstream	3	2	1	5	0	0	0	0	0	0	5	3	19
BG06	**Average %**	**100%**	**67%**	**50%**	**23%**	**0%**	**22%**	**25%**	**33%**	**60%**	**67%**	**100%**	**100%**	**42%**
BG07-1c	Upstream center	2	1	0	0	0	0	0	0	0	0	0	1	4
BG07-1l	Upstream left	1	0	0	0	0	0	0	0	0	0	0	2	3
BG07-1r	Upstream right	3	5	8	10	12	11	10	11	1	2	1	0	74
BG07-2c	Middle center	3	5	8	5	0	0	0	0	0	0	0	2	23
BG07-2l	Middle left	0	0	0	0	0	0	0	0	0	0	1	3	4
BG07-2r	Middle right	3	5	8	9	11	6	8	2	0	0	0	1	53
BG07-3c	Downstream center	3	5	5	0	0	0	0	0	0	0	0	1	14
BG07-3l	Downstream left	2	0	0	0	0	0	0	0	0	0	0	2	4
BG07-3r	Downstream right	3	5	8	9	3	2	0	0	0	0	0	2	32
BG07	**Average %**	**74%**	**58%**	**51%**	**37%**	**24%**	**18%**	**17%**	**12%**	**1%**	**3%**	**4%**	**52%**	**23%**
BG08-1c	Upstream center	3	5	8	10	12	8	1	0	0	0	3	3	53
BG08-1l	Upstream left	3	5	8	10	11	6	0	0	0	5	5	3	56
BG08-1r	Upstream right	3	5	8	10	12	8	11	1	0	0	1	2	61
BG08-2c	Middle center	3	5	7	9	8	7	0	0	0	3	5	3	50
BG08-2l	Middle left	3	5	7	7	2	2	0	0	0	4	4	3	37
BG08-2r	Middle right	3	5	7	9	11	10	2	0	0	1	4	3	55
BG08-3c	Downstream center	3	3	0	0	0	0	0	10	5	0	0	2	23
BG08-3l	Downstream left	3	5	3	0	0	0	0	9	5	0	0	3	28
BG08-3r	Downstream right	1	0	0	0	0	0	0	7	9	1	0	2	20
BG08	**Average %**	**93%**	**84%**	**67%**	**61%**	**52%**	**38%**	**13%**	**25%**	**21%**	**19%**	**49%**	**89%**	**43%**

ATTACHMENT D
FIELD NOTES

St. Regis TMDL Planning Area

Twelvemile Creek

Solar Pathfinder Site	Stream Aspect	Wetted Width (Feet)	Bankfull Width (Feet)	Dominant Tree Species	Dominant Tree Height (Feet)	Primary Shade Controlling Factor	Secondary Shade Controlling Factor	Description	Visible Anthropogenic Impacts
TM01-1	0	6.5	10.6	PIEN	72	conifers	alders, topography	Dense alder understory w/conifers in overstory, PIEN, PICO, PSME, ABGR	Road present on river left, some hillslope logging, but retained riparian corridor
TM01-2	0	10.1	13.2	ABLA	86	conifers	alders, topography	Small stream with subalpine fir overstory mixed with Doug Fir, young and old cedars, Engelmann spruce, lots of shade representing more natural/potential conditions	Road present about 100 ft from channel
TM01-3	0	8.3	11.4	ABLA	92	conifers	alders, topography	PIEN, THPL, ABLA, PSME, present	Road further confines channel in small valley bottom in areas
TM02-1	0	5.8	9.1	ABLA	39	conifers	alders, topography	ABLA, THPL, alder, red osier, PIEN, present: many trees are taller than the ones accounting for the shade at the site	Several clearcuts along right side of river w/minimal riparian buffer, stumps present along bank=riparian harvest
TM02-2	0	17.1	19.4	PIEN	111	conifers	alders, topography	Dense alders along channel	Clearcut/road on river left (just upstream) and clearcut along right, though there is a band of conifers along channel
TM02-3	0	18.8	23.9	ABLA	65	conifers	alders, topography	Road is along river right abutting channel in places with a narrow band of spruce and alder at bankfull	A road limits the riparian vegetation on river right and hillslope cut
TM03-1	0	18.0	25.1	PIEN	147	conifers	alders, topography	Medium size stream with Red osier, alder, Engelmann spruce, subalpine fir, larch, cedar trees present	Road present about 100 ft from channel, a few old cut stumps present in riparian zone
TM03-2	0	20.6	31.8	ABLA	103	conifers	alders, topography	Medium size stream with Red osier, alder, Engelmann spruce, subalpine fir, larch, cedar trees present	Road along river right with narrow band of conifers and alders
TM03-3	0	20.0	29.9	Alder	25	conifers	alders, topography	Medium size stream with Red osier, alder, Engelmann spruce, subalpine fir, larch, cedar trees present	Stream is primarily away from road
TM04-1	45	28.8	36.4	PICO	81	conifers	alders, topography	Alder and red osier, PIPO, ABLA, PSME, THPL, Larch present	Road along river left, some shrubs and sparse conifers on hillslope
TM04-2	0	24.3	30.6	LAOC	102	conifers	alders, topography	Valley is becoming more open with Sub Alpine fir, Engelmann spruce, larch, grand fir, cedar, lodgepole, ponderosa, Douglas fir, cottonwoods and alders	Road is present, but up higher on the hilslope
TM04-3	45	18.2	25.1	Cottonwoods	85	alders	alders, topography	Some cottonwoods, and conifers, alders, PICO encroaching on floodplain	Site is below Cabin City campground, it appears channelized or entrenched w/ loss of riparian forest, old channels present on floodplain suggesting channel relocation
TM05-1	0	27.4	32.1	PIEN	70	conifers	alders, topography	River left has mostly conifers, river right appears to be a former cottonwood gallery w/sparse shrubs and PICO, PIEN	Upstream channelization leading to overwidening and bank erosion limiting shrub development
TM05-2	45	20.7	28.4	PIEN	102	conifers	alders, topography	Limited shade, grassy, small alders present and sparse conifers	Roads and timber harvest led to loss of riparian and hillslope vegetation
TM05-3	0	19.5	26.7	ABLA	73	conifers	alders, topography	Mature cottonwoods present on river right, mostly conifers on river left	Logging and road building reduces shade
TM06-1	0	26.3	32.6	PSME	72	alders	topography	PSME and large PIPO along river right w/ABLA, Alder on river left w/some cottonwoods farther back	Road fill across Rock and Twelvemile creek, floodplain dynamic alteration

ABGR	Grand fir
ABLA	Subalpine fir
PICO	Lodgepole pine
PIMO	White pine
PIPO	Ponderosa pine
PIEN	Engelmann spruce
PSME	Douglas fir
THPL	Western red cedar

Big Creek

Solar Pathfinder Site	Stream Aspect	Wetted Width (Feet)	Bankfull Width (Feet)	Dominant Tree Species	Dominant Tree Height (Feet)	Primary Shade Controlling Factor	Secondary Shade Controlling Factor	Description	Visible Anthropogenic Impacts
BG1-1	0	15.6	19.5	ABLA	72	conifers	alders, topography	Dense conifer forest (ABLA, THPL, PIEN)	Road encroachment in places, upstream harvest?, stream becomes much smaller upstream of site, historic logging of THPL
BG1-2	45	21.8	30.8	ABGR	114	conifers	alders, topography	Dense THPL, near where confined canyon opens up, wide B3 channel, some red osier, mountain maple, willow along margin, also, ABGR, THPL with good overhang, 80% approx.	Historic THPL logging present in riparian
BG1-3	90	12.7	24.6	ABGR	31	conifers	alders, topography	ABGR, ABLA, Larch, PIEN and shrubs present	Road clearing at lower end of site
BG2-1	90	23.5	32.5	Willow	6	willow	conifers	Shrubs with some PSME, PICO, PIEN, ABGR, cottonwoods, with wide channel and some bank erosion	Riparian harvest present
BG2-2	90	dry	22.2	Willow	8	willow	conifers	Channel is dry! Larch, PICO, ABLA, PSME, ABGR, on river right, left side has willows, red osier, and some cottonwoods	Current harvest along river right above low bench, 47' from river right to top of bench, fully cleared at 90', SMZ flagging at 75'.
BG2-3	90	dry	22.4	Cottonwoods	33	willow	cottonwoods	Channel is dry! Cottonwoods w/shrubs present, willows are moving into the channel	Logging present, w/floodplain buffer
BG3-1	0	15.3	24.1	ABGR	40	conifers	alders, topography	Conifers along channel, logging influences shade in the late afternoon, ABGR, PIEN, THPL, some cottonwoods, Mountain maple, Red osier, ABLA and PSME present	Clearcut along river right that reduces shade some, historic (stumps) along river left
BG3-2	45		22.9	PIEN	140	conifers	alders, topography	Dense cedars along river right (with historic logging), some PIEN and riparian shrubs present	Road and logging, both have forest buffer along stream
BG3-3	0	18.0	24.8	THPL	86	conifers	alders	Lots of cedar with PIEN, ABGR, this looks like PNC w dense cedar bottom, deadfall across channel.	Minimal, a few stumps from historic logging
BG4-1	0	12.1	17.2	THPL	107	conifers	alders, topography	THPL, ABLA, also some PSME, PIEN, ABGR and red osier	Some logging on river left, road fairly close to stream, but w/adequate buffer, stumps on river right too
BG4-2	45	10.9	18.4	ABLA	79	conifers	alders, topography	PIEN, ABLA, PICO and cottonwoods present	Doesn't appear disturbed, more open meadow character.
BG4-3	0	15.3	23.9	Cottonwoods	10	alder	cottonwoods	Narrow band of cottonwoods/alders/willows, then gravel and dry floodplain with cottonwoods and conifers	Appears to have been some sort of sediment pulse w/large bar deposits, dry/cobble floodplain w/many cedar stumps
BG5-1	90	17.4	21.7	PIEN	128	conifers	alders, topography	PIEN, ABLA, THPL, PICO, ABGR, with alder, red osier, willows along stream	Road along river right encroaches in places
BG5-2	90	17.9	23.9	PIEN	128	conifers	alders, topography	PIEN, ABLA, THPL, PICO, ABGR, with alder, red osier, willows along stream	Road crossing obliterated and pools added, plus bank stabilization project upstream
BG5-3	90	17.0	19.5	PIEN	128	conifers	alders, topography	PIEN, ABLA, THPL, PICO, ABGR, with alder, red osier, willows along stream	Doesn't appear to have been harvested, except for road, which reduces shade on south side of the river
BG6-1	-45	12.2	23.1	PIEN	37	conifers	alders	Dense ABLA, Larch, THPL, PSME, PIEN on river right with PIEN, PICO cottonwood on river left, alders on both sides	Potential historic clearing along river left, river right is forested, road crossing upstream
BG6-2	0	14.8	19.2	Cottonwoods	85	alder	conifers	Larch, ABLA, THPL, ABGR on river right with cottonwoods, PICO, PIPO, THPL, PSME on river left	Appears that stream has shifted on floodplain, potential due to increase sediment/discharge from upper watershed due to logging/burns
BG6-3	-45	10.0	21.7	Cottonwoods	57	alder	conifers	Some conifers on floodplain w/scattered large cottonwoods	Some road encroachment and an altered floodplain?
BG7-1	90	17.6	42.5	Willow	12	willow	willow	Primarily willow corridor along channel with some alder and cottonwood (farther back on floodplain)	Road on both sides, upstream land mgmt alters sediment and flow regimes, road abuts channel along minor potions of reach
BG7-2	45	16.8	40.4	Willow	12	willow	willow	Primarily willow corridor along channel with some alder and cottonwood (farther back on floodplain)	Road on both sides, upstream land mgmt alters sediment and flow regimes, road abuts channel along minor potions of reach
BG7-3	90	25.2	40.1	Willow	12	willow	willow	Primarily willow corridor along channel with some alder and cottonwood (farther back on floodplain)	Road on both sides, upstream land mgmt alters sediment and flow regimes, road abuts channel along minor potions of reach
BG8-1	90	33.4	56.3	ABLA	84	conifers	topography	River right: ABLA, THPL, larch, PIMO on left: PIMO, PICO, farther back w/alder, willow, some cottonwood and ABLA.	Minimal impacts
BG8-2	90	25.5	34.0	PIXX	49	conifers	topography	Aspect limits shade available by conifers	Minimal impacts
BG8-3	90	22.0	35.8	Cottonwoods	81	willow	cottonwoods	Sparse mature cottonwoods with conifers encroaching on floodplain	Fence along river right and PICOs suggest disturbance, bridge upstream appears to create a “flume” with fill across floodplain, wide open gravel area w/bank erosion, not much bank vegetation downstream

ATTACHMENT E
CANOPY DENSITY DATA

St. Regis TMDL Planning Area

AERIAL ASSESSMENT			DENSIOMETER							
Reach	**Canopy Density**	**Canopy Type**	**Site ID**	**Canopy Type**	**Reading 1** (# of dots covered by canopy)		**Reading 2** (# of dots covered by canopy)		**Latitude**	**Longitude**
1.0	75%	Cottonwoods	**SR 1.0-1**	mature cottonwoods with shrub understory	**N**	54	**N**	68	47.29661	-115.09355
					E	73	**E**	66		
					S	82	**S**	83		
					W	72	**W**	80		
1.7	55%	Cottonwoods	**SR 1.7-1**	cottonwood and conifer overstory with shrub understory	**N**	73	**N**	79	47.29050	-115.16186
					E	45	**E**	46		
					S	49	**S**	50		
					W	68	**W**	69		
1.9	55%	Cottonwoods	**SR 1.9 -1**	mature cottonwoods with alder, red osier understory, some larch/pine	**N**	52	**N**	49	47.29450	-115.16860
					E	40	**E**	37		
					S	70	**S**	72		
					W	81	**W**	81		
4.1	45%	Cottonwoods	**SR 4.1-1**	mature/decadent cottonwoods, alders, fir, spruce, pine	**N**	18	**N**	26	47.35431	-115.29517
					E	60	**E**	58		
					S	15	**S**	25		
					W	56	**W**	71		
5.0	50%	Cottonwoods	**SR 5.0-1**	decadent cottonwoods, sprouts, confiers	**N**	53	**N**	40	47.37762	-115.36024
					E	77	**E**	78		
					S	41	**S**	39		
					W	53	**W**	58		
5.4	35%	Cottonwoods	**SR 5.4-1**	cottonwood, spruce, pine, willows	**N**	50	**N**	48	47.38799	-115.40713
					E	52	**E**	51		
					S	5	**S**	7		
					W	23	**W**	24		
5.3	45%	Cottonwoods	**SR 5.3-1**	cottonwoods, pine, herbaceous understory	**N**	58	**N**	53	47.38610	-115.40384
					E	70	**E**	73		
					S	18	**S**	22		
					W	33	**W**	33		
5.5	35%	Cottonwoods	**SR 5.5-1**	mature cottonwoods, herbaceous understory, young pine	**N**	36	**N**	32	47.38900	-115.41354
					E	43	**E**	51		
					S	55	**S**	50		
					W	54	**W**	53		
5.7	25%	Cottonwoods	**SR 5.7-1**	pole cottonwoods, young pine	**N**	31	**N**	35	47.39281	-115.42304
					E	29	**E**	28		
					S	23	**S**	32		
					W	21	**W**	18		
7.5	75%	Conifers	**SR 7.5-1**	fir, spruce, larch, pine	**N**	78	**N**	76	47.41337	-115.58675
					E	80	**E**	88		
					S	92	**S**	91		
					W	88	**W**	80		
7.5	55%	Cottonwoods	**SR 7.5-2**	pine, fir, spruce	**N**	47	**N**	45	47.41418	-115.58592
					E	75	**E**	79		
					S	68	**S**	56		
					W	23	**W**	14		
7.7	85%	Conifers	**SR 7.7-1**	larch, fir, spruce, cedar	**N**	78	**N**	82	47.41725	-115.59615
					E	85	**E**	84		
					S	95	**S**	96		
					W	62	**W**	65		